Role of Mixed Collector Systems in Selective Separation of Albite from Greek Stefania Feldspar Ore

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ABSTRACT: The adsorption behaviour of mixed cationic alkyl diamine and anionic sulfonate/oleate collectors and a combined cationic-anionic collector, N-tallow 1, 3-propane diamine dioleate (Duomeen TDO) at acidic pH values on albite and quartz minerals was investigated through Hallimond flotation, electrokinetic and diffuse reflectance FTIR studies. The reagent schemes are tested in bench scale flotation for the separation of albite from Greek Stefania feldspar ore. The single mineral flotation tests showed the feasibility of selective albite flotation from quartz at pH 2 where the doubly positively charged collector species adsorb on albite but not on quartz. However, the adsorption behaviour of mixed collectors on albite and quartz at the same pH value, as evidenced from zeta-potential and FTIR studies, is almost similar. The IR spectra show the co-existence of neutral oleic acid together with charged amine species at low pH values. The bench scale flotation results indeed showed that selective albite flotation takes place only after desliming the feed material. An albite concentrate exceeding 10 Wt% Na_2O content is produced from a material containing about 6.5 wt% Na_2O, where an albite product more than 9 wt% Na_2O is considered to be valuable.

1. INTRODUCTION

Feldspar is the most widespread important mineral group in the world, forming around 60% of the earth's crust, and is used in glass manufacturing, in the production of ceramics and in value added applications such as fillers and extenders in plastics, paint and rubber (Bolger, 1995). The froth flotation process has so far proved to be the most suitable beneficiation method. Conventionally, feldspars are separated from quartz using cationic long-chain alkyl amine collector in highly acidic conditions generated by the use of hydrofluoric acid. The use of HF is no longer acceptable due to environmental considerations and a new reagent schemes, free from HF, have been reported from time to time (Hanumantha Rao and Forssberg, 1994; Vidyadhar et al., 2002, Vidyadhar and Hanumantha Rao, 2007).

The aim of the present work is to study the adsorption behaviour of cationic mixed alkyl diamine and anionic sulfonate/oleate collectors and a combined cationic-anionic collector, N-tallow 1, 3-propane diamine dioleate on albite and quartz minerals for understanding of the interaction mechanism and also apply the above mentioned reagent schemes for the selective albite flotation from Stefania feldspar deposit of Mevior S.A., Greece.

2. EXPERIMENTAL

2.1 Materials

The pure crystalline quartz and albite mineral samples were obtained from Mevior S.A., Greece. The chemical analysis of these samples showed that quartz purity is more than 99% and albite is 98.5% pure with oxides content of 67.9 wt% SiO_2, 19.2 wt% Al_2O_3 and 11.7 wt% Na_2O. The BET specific surface areas for albite coarser (–150+38 μm) and fine fractions (–5 μm) were determined to be 0.15 and 2.78 $m^2\ g^{-1}$ and the respective specific surface areas for quartz size fractions were found to be 0.09 and 1.30 $m^2\ g^{-1}$.

The albite ore from the Stefania deposit near Thessaloniki, Greece was also received from Mevior S.A. The ore was crushed to –3 mm size and the crushed material was ground in a stainless steel rod mill in order to obtain a suitable size fraction for bench-scale flotation tests. The tests were performed with a particle size distribution of d_{80} = 90 μm (80% passing through size). The material contained about 75.8 wt% SiO_2, 13.7 wt% Al_2O_3, 6.85 wt% Na_2O, 0.54 wt% Fe_2O_3, 0.85 wt% K_2O and 0.43 wt% CaO.

2.2 Reagents

The collectors of N-tallow-1,3-diaminopropane (Duomeen T) and N-tallow-1,3-propanediamine dioleate (Duomeen TDO) were obtained from Akzo Nobel AB, Sweden and anionic alkyl aryl sulfonate (Morwet 3008) collector was obtained from Witco SA, France.

2.3 Zeta-potential Measurements

Zeta-potentials were determined using a Laser Zee Meter (Pen Kem Inc., model 501) equipped with video system apparatus employing a flat cell. About 1.0 g l^{-1} of mineral suspension was prepared in 10^{-3} KNO_3 supporting electrolyte solutions and conditioned for 1 hour at room temperature (22°C) in the presence of predetermined collector concentration and pH.

2.4 Diffuse Reflectance FTIR Measurements

The infrared spectra were recorded for all the samples after zeta-potential measurements on the air-dried –5 μm powder. The FTIR spectra were obtained with a Perkin-Elmer 2000 spectrometer with its own diffuse reflectance attachment. Typical spectrum was an average of 200 scans measured at 4 cm^{-1} resolution with a narrow band liquid nitrogen cooled MCT detector.

2.5 Hallimond Flotation Tests

The single mineral flotation tests were made using Hallimond flotation cell of 100 ml capacity. Exactly 1 g of the mineral was conditioned for 5 min at the desired pH and predetermined collector concentration solution in a 100 ml volumetric flask. The suspension was then transferred to the Hallimond tube. The flotation was conducted for 1 min at constant agitation and aeration rate of 8 ml min^{-1}.

2.6 Bench Scale Flotation Tests

Bench scale flotation tests were performed with 1 Kg material in a WEMCO laboratory cell of the Fagergren type with a cell volume of 2.7 litres. Initially, 1 Kg of the material was ground in a stainless steel rod mill of 17 Kg charge with 800 ml water for specified time interval. After grinding, the material was deslimed at 20 μm size and transferred to the flotation cell. The pulp density was adjusted to 28 per cent and the sequential flotation tests were conducted with different reagent schemes.

3. RESULTS AND DISCUSSION

3.1. Hallimond Flotation Studies

The flotation responses of albite and quartz as a function of pH at two initial diamine concentrations are given in Figure 1. Results show that albite recovery at pH 2 is about 40% at diamine collector concentration of 1×10^{-5} M, whereas quartz is non-floatable. The albite and quartz recoveries are dependent on the diamine concentration in the pH region 3 to 5. Above pH 5, the flotation responses of both minerals are identical with 90% recovery, irrespective of the diamine concentration used. Thus, the diamine collector floats albite partially at pH 2 without influencing quartz flotation.

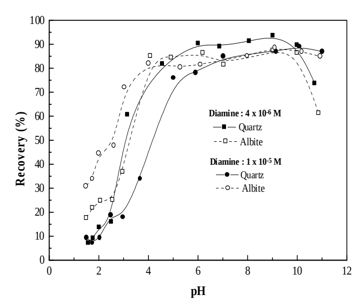

Fig. 1: Flotation results as a function of pH at two initial diamine collector concentrations.

The effect of pH on albite and quartz flotation at two initial Duomeen TDO collector concentrations of 4×10^{-6} M and 1×10^{-5} M is shown in Fig. 2. The results show that albite floats selectively within the narrow acidic pH region of 1.75-2.0. In this pH region, the albite recovery is about 70 to 100% where quartz flotation hardly attains 20% recovery. However, at and above pH 3, both minerals have similar flotation response of about 80-95% recovery.

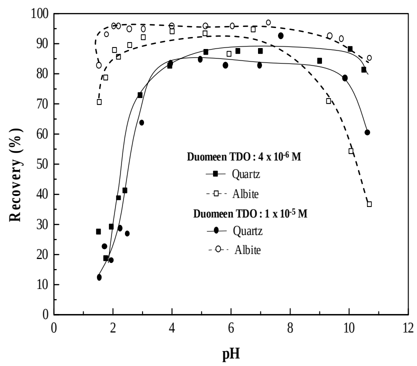

Fig. 2: Flotation results as a function of pH at two initial diamine collector concentrations.

3.2. Zeta-potential Studies

The zeta-potentials of quartz and albite as a function of pH are presented in Fig. 3. The results indicate that the iso-electric point of quartz is at pH 2 and the albite displays negative charge down to pH 2. An extension of albite curve indicates of its iep at about pH 1.6. It is important to note that albite is negatively charged at pH $\leq$ 2 where it responds partially with diamine while quartz is almost uncharged.

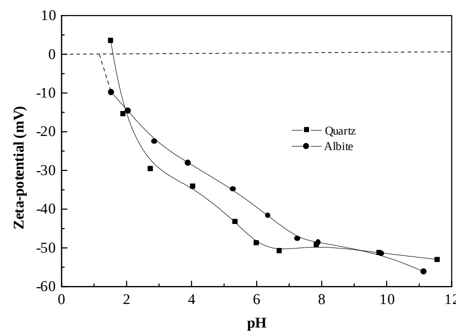

Fig. 3: Zeta-potentials of quartz and albite as a function of pH in 0.001M KNO_3

3.3 Diffuse Reflectance FTIR Studies

The reference DRIFT spectra of alkyl diamino-propane dioleate (Duomeen TDO), alkyl diamin-opropane (Duomeen T) and sodium oleate collectors, and the quartz and albite minerals are depicted in Fig. 4. The spectra of collectors show the bands characteristic of alkyl chains, $\nu_{as}(CH_3)$, $\nu_{as}(CH_2)$ and $\nu_s(CH_2)$ groups, at 2956 cm^{-1}, 2924 cm^{-1} and 2850 cm^{-1} respectively (Bellamy, 1975). A sharp intensity band at 3332 cm^{-1} appears in the diamine spectrum due to $\nu_{as}(NH_2)$ and $\nu_s(NH_2)$, which is absent in the diamine-dioleate spectrum signifying that the amine groups are protonated and very likely complexed with the carboxylic groups of oleate.

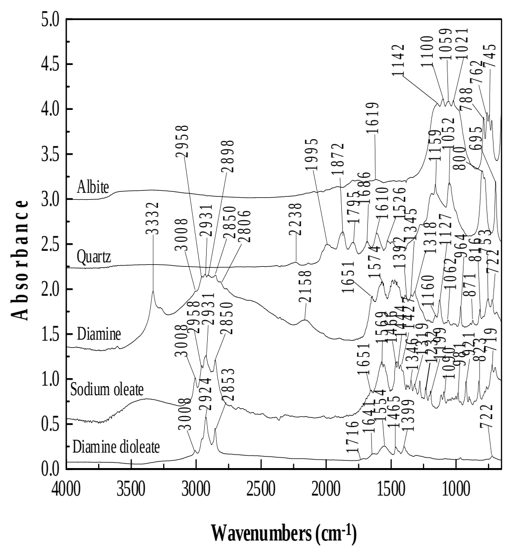

Fig. 4: Reference DRIFT IR/spectra of alkyl diamine-dioleate, sodium oleate, diamine, quartz and albite

3.3. Bench Scale Flotation Tests

Based on the Hallimond flotation results, the material after wet grinding is deslimed at 20- μm prior to bench-scale flotation tests. Typical flotation test results are shown in Tables 1 and 2. The results show that an albite concentrate with Na_2O content more than 10% is achieved in every step of albite flotation and there is a good selectivity between quartz and albite.

Table 1: Flotation results of stefania albite ore with mixed alkyl diamine and sulfonate collectors

Product	Wt (%)	Assay (%)					Distribution (%)				
		SiO_2	Al_2O_3	Fe_2O_3	K_2O	Na_2O	SiO_2	Al_2O_3	Fe_2O_3	K_2O	Na_2O
-20 μm	24.39	70.50	15.90	1.53	1.05	7.67	22.7	27.8	52.7	30.9	27.1
1. Mica	9.66	71.50	16.20	1.01	2.44	5.29	9.1	11.2	13.8	28.5	7.4
2. Mica	5.87	76.40	13.50	0.57	0.98	6.52	5.9	5.7	4.7	6.9	5.5
3. Albite	17.97	70.10	18.10	0.33	0.70	**9.63**	16.6	23.3	8.3	15.3	25.0
4. Albite	10.49	70.40	18.40	0.30	0.60	**10.10**	9.8	13.8	4.5	7.5	15.3
5. Albite	2.54	70.00	17.60	0.31	0.60	**9.65**	2.3	3.2	1.1	1.8	3.5
Tailings	29.07	89.30	7.19	0.36	0.26	3.83	33.5	15.0	14.9	9.0	16.1
Feed (est.)	99.99	75.73	13.96	0.71	0.83	6.51	100	100	100	100	100

Table 2: Flotation results of stefania albite ore using diamine-dioleate collector

Product	Wt (%)	Assay (%)					Distribution (%)				
		SiO_2	Al_2O_3	Fe_2O_3	K_2O	Na_2O	SiO_2	Al_2O_3	Fe_2O_3	K_2O	Na_2O
-20 μm	24.39	70.50	15.90	1.53	1.05	7.67	22.6	28.37	54.30	37.67	26.97
1. Mica	7.16	71.50	16.20	1.01	2.44	5.29	6.73	8.49	10.52	23.65	5.46
2. Mica	5.08	76.40	13.50	0.57	0.98	6.52	6.10	5.02	4.21	6.74	4.78
3. Albite	5.13	67.90	20.20	0.39	1.10	10.10	4.58	7.58	2.91	7.64	7.47
4. Albite	12.06	67.10	18.00	0.24	0.50	10.30	10.64	15.88	4.21	8.16	17.91
5. Albite	11.24	68.90	17.50	0.37	0.46	9.87	10.18	14.39	6.05	7.30	16.00
Tailings	34.94	87.50	7.93	0.35	0.25	4.25	40.18	20.27	17.79	11.83	21.41
Feed (est.)	100.0	76.09	13.67	0.69	0.74	6.24	100	100	100	100	100

4. CONCLUSIONS

1. The iso-electric points of albite and quartz are at pH 1.6 and 2.0 respectively so that partial flotation of albite and no flotation of quartz occurred with alkyl diamine at pH 2. The partial diamine flotation of albite is increased with the presence of sulfonate without effecting quartz flotation.
2. The difference in the results at pH 2 between the Hallimond flotation (where selective albite flotation is observed) and zeta-potential/FTIR studies (where similar adsorption behaviour on albite and quartz is noticed) is attributed to the coarse and fine particles employed in these studies respectively. The adsorption of alkyl ammonium ions on surface silanol groups through hydrogen bonding is presumed to be reason for similar adsorption behaviour on fine albite and quartz particles.
3. However, the results are in agreement with the bench scale flotation results of feldspar ore material, where selective albite flotation is accomplished at pH 2, only after desliming the feed material.

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